US009322577B2

(12) **United States Patent**
Chaudhry et al.

(10) **Patent No.: US 9,322,577 B2**
(45) **Date of Patent: Apr. 26, 2016**

(54) **WATER HEATER APPLIANCES AND METHODS FOR OPERATING SAME**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 142 days.

(21) Appl. No.: **14/188,764**

(22) Filed: **Feb. 25, 2014**

(65) **Prior Publication Data**

US 2015/0241093 A1 Aug. 27, 2015

(51) **Int. Cl.**

F25B 29/00	(2006.01)
F25B 6/04	(2006.01)
F24D 17/02	(2006.01)
F28D 20/00	(2006.01)

(52) **U.S. Cl.**

CPC . ***F25B 6/04*** (2013.01); ***F24D 17/02*** (2013.01); ***F28D 20/00*** (2013.01); *F24D 2200/08* (2013.01); *F24D 2200/12* (2013.01); *F25B 2339/047* (2013.01); *F25B 2341/0012* (2013.01); *F25B 2341/0662* (2013.01); *F25B 2500/01* (2013.01)

(58) **Field of Classification Search**

CPC F25B 29/003; F25B 29/00; F25B 30/02; F25B 6/04; F25B 2339/047; F25B 2341/0012; F25B 2341/0662; F25B 2500/01; F24D 2200/12; F24D 2200/08

USPC 62/238.6, 160, 79

See application file for complete search history.

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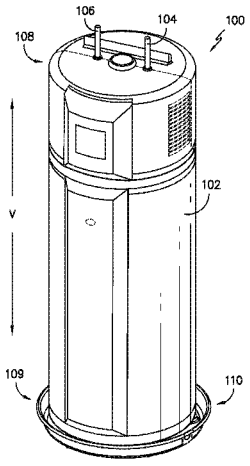
(57) **ABSTRACT**

Water heater appliances and methods for operating water heater appliances are provided. A water heater appliance includes a tank defining an interior volume, and a sealed system for heating water within the interior volume. The sealed system includes a compressor operable to compress refrigerant, and a first condenser downstream of and in fluid communication with the compressor. The first condenser is operable to heat water within the interior volume using energy from the refrigerant. The sealed system further includes a second condenser downstream of and in fluid communication with the first condenser. The second condenser is operable to heat water within the interior volume using energy from the refrigerant. The sealed system further includes an evaporator between and in fluid communication with the second condenser and the compressor.

14 Claims, 3 Drawing Sheets



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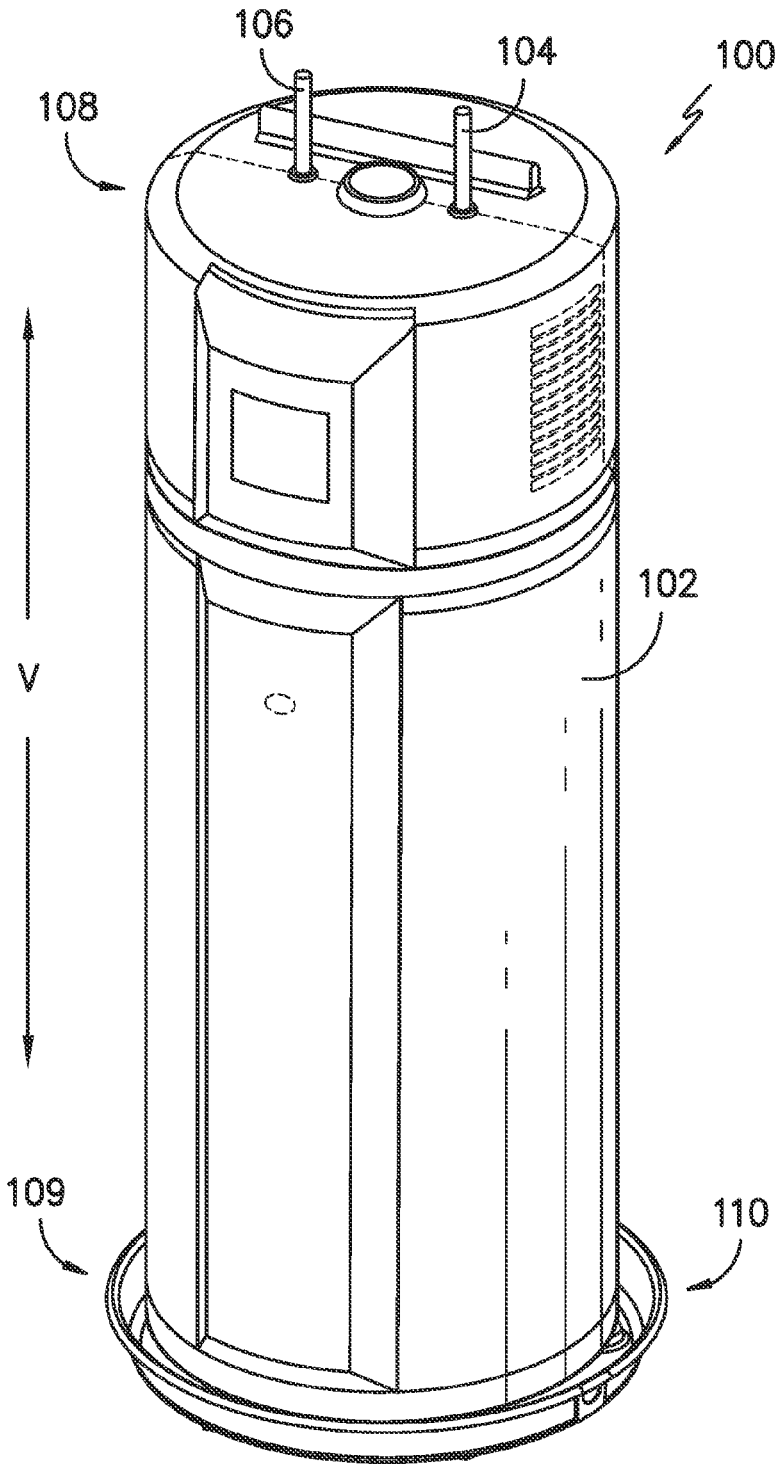
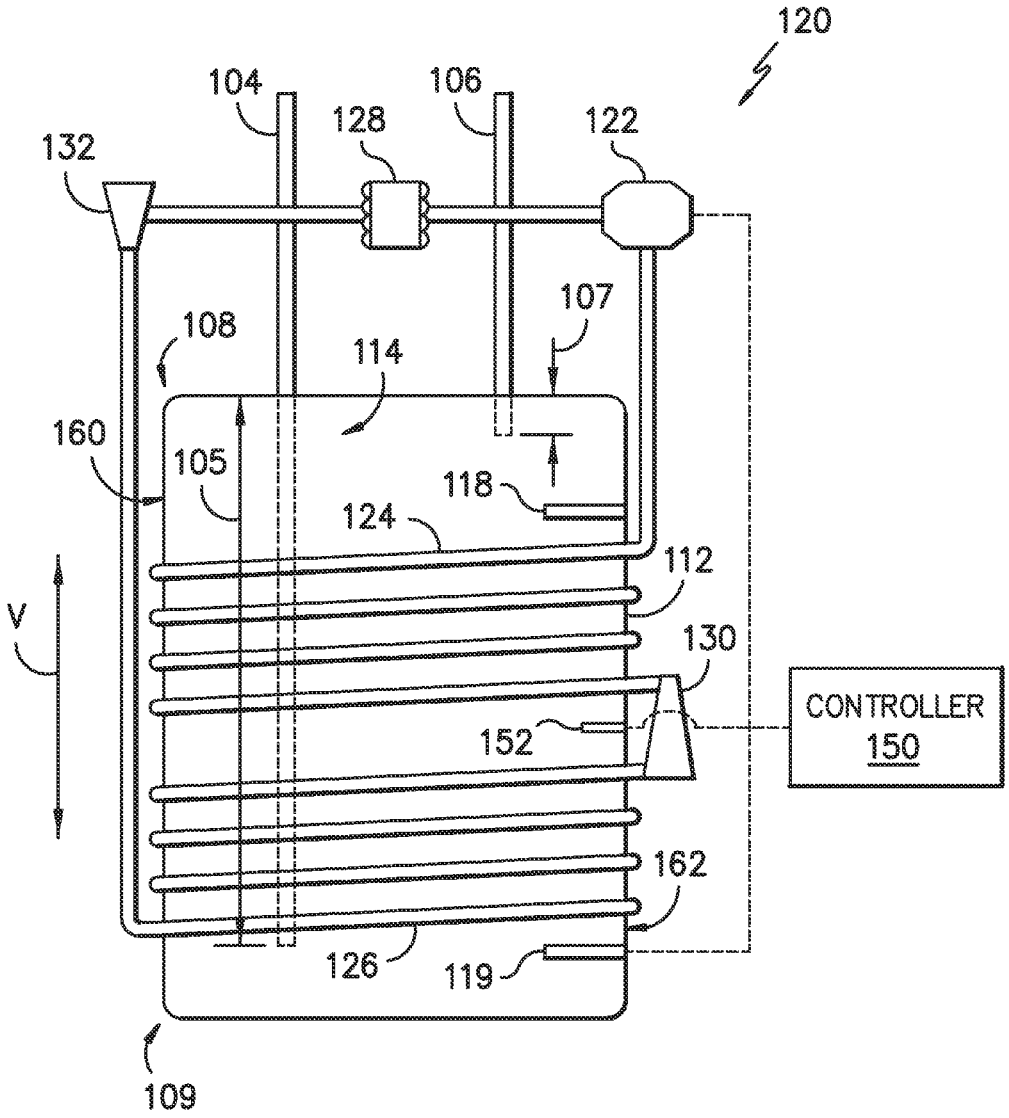


FIG. 1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128
122
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107
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CONTROLLER
150
152
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126
119
109

FIG. 2

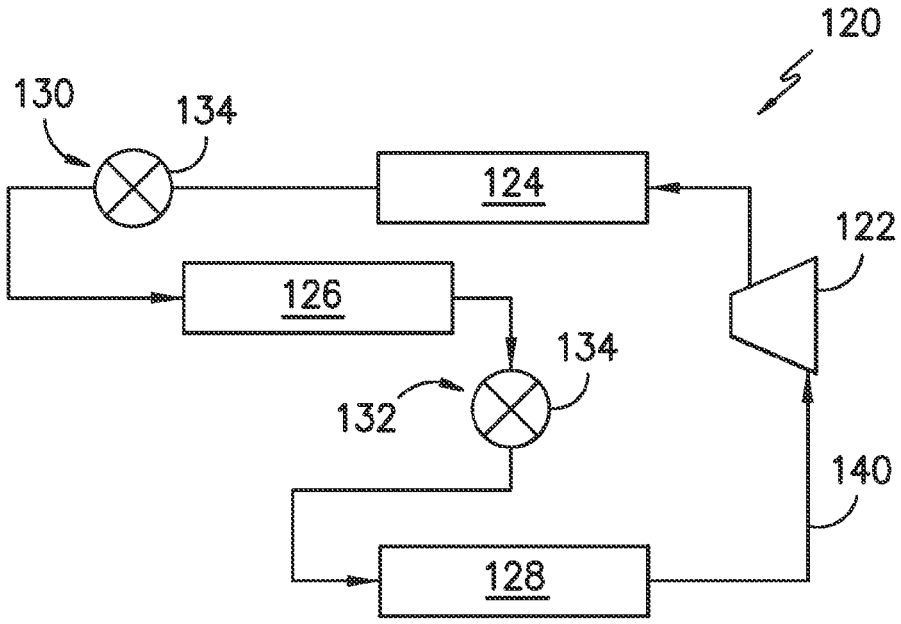
120
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FIG. 3

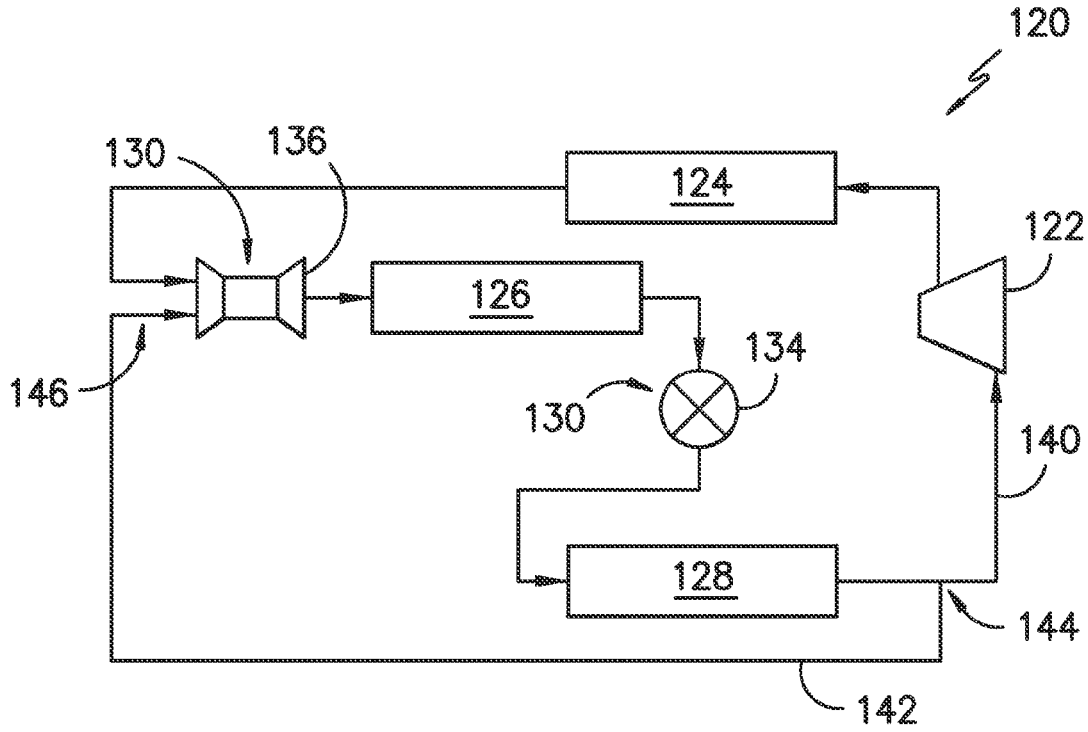
120
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FIG. 4

WATER HEATER APPLIANCES AND METHODS FOR OPERATING SAME

FIELD OF THE INVENTION

The present subject matter relates generally to water heater appliances, such as heat pump water heater appliances, and methods for operating the same.

BACKGROUND OF THE INVENTION

Certain water heaters operate such that water within the water heater's tank is heated to a set temperature. Generally, a user can select the set temperature using a dial or other input on the water heater. Heat pump water heaters are gaining broader acceptance as a more economic and ecologically-friendly alternative to electric water heaters. Heat pump water heaters include a sealed system for heating water to the set temperature. Certain heat pump water heaters also include a supplemental or auxiliary heating element for heating water. Sealed systems are generally more efficient than auxiliary heating elements.

A typical sealed system includes a compressor, a condenser, a throttling device, and an evaporator. These components operate in a closed loop to manipulate a refrigerant. The refrigerant in turn exchanges energy with water in the tank of the water heater, heating the water.

As consumer demand and government regulation continue to encourage the development of high efficiency, low energy appliances, improvements to presently known appliance designs are desired. In particular, increases in efficiency and decreases in energy usage of presently known water heater appliances are desired.

BRIEF DESCRIPTION OF THE INVENTION

In accordance with one embodiment of the present disclosure, a water heater appliance is provided. The water heater appliance includes a tank defining an interior volume, and a sealed system for heating water within the interior volume. The sealed system includes a compressor operable to compress refrigerant, and a first condenser downstream of and in fluid communication with the compressor. The first condenser is operable to heat water within the interior volume using energy from the refrigerant. The sealed system further includes a second condenser downstream of and in fluid communication with the first condenser. The second condenser is operable to heat water within the interior volume using energy from the refrigerant. The sealed system further includes an evaporator between and in fluid communication with the second condenser and the compressor.

In accordance with another embodiment of the present disclosure, a method for operating a water heater appliance is provided. The method includes flowing a refrigerant through a compressor, flowing the refrigerant from the compressor through a first condenser surrounding a tank of the water heater appliance, and flowing the refrigerant from the first condenser through a second condenser surrounding the tank of the water heater appliance.

These and other features, aspects and advantages of the present invention will become better understood with reference to the following description and appended claims. The accompanying drawings, which are incorporated in and constitute a part of this specification, illustrate embodiments of the invention and, together with the description, serve to explain the principles of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

A full and enabling disclosure of the present invention, including the best mode thereof, directed to one of ordinary skill in the art, is set forth in the specification, which makes reference to the appended figures.

FIG. **1** provides a perspective view of a water heater appliance in accordance with one embodiment of the present disclosure;

FIG. **2** provides a schematic view of various components of a water heater appliance in accordance with one embodiment of the present disclosure;

FIG. **3** provides a schematic diagram of a sealed system for use with a water heater appliance in accordance with one embodiment of the present disclosure; and

FIG. **4** provides a schematic diagram of a sealed system for use with a water heater appliance in accordance with another embodiment of the present disclosure.

DETAILED DESCRIPTION

Reference now will be made in detail to embodiments of the invention, one or more examples of which are illustrated in the drawings. Each example is provided by way of explanation of the invention, not limitation of the invention. In fact, it will be apparent to those skilled in the art that various modifications and variations can be made in the present invention without departing from the scope or spirit of the invention. For instance, features illustrated or described as part of one embodiment can be used with another embodiment to yield a still further embodiment. Thus, it is intended that the present invention covers such modifications and variations as come within the scope of the appended claims and their equivalents.

FIG. **1** provides a perspective view of a water heater appliance **100** according to an exemplary embodiment of the present subject matter. FIG. **2** provides a schematic view of various components of a water heater appliance **100**. Water heater appliance **100** includes a casing **102**. A tank **112** (FIG. **2**) is mounted within casing **102**. Tank **112** defines an interior volume **114** for heating water therein.

Water heater appliance **100** includes a cold water conduit **104** and a hot water conduit **106** that are both in fluid communication with tank **112** within casing **102**. As an example, cold water from a water source, e.g., a municipal water supply or a well, enters water heater appliance **100** through cold water conduit **104**. From cold water conduit **104**, such cold water enters interior volume **114** of tank **112** wherein the water is heated to generate heated water. Such heated water exits water heater appliance **100** at hot water conduit **106** and, e.g., is supplied to a bath, shower, sink, or any other suitable feature.

Cold water conduit **104** and hot water conduit **106** each extend into the interior volume **114**. Further, the cold water conduit defines a length **105** within the interior volume **114** and the hot water conduit **106** defines a length **107** within the interior volume **114**. The lengths **105**, **107** are the lengths of the portions of the cold and hot water conduits **104**, **106** that are disposed within the interior volume **114**. In exemplary embodiments, the length **105** of the cold water conduit **104** within the interior volume **114** is greater than the length **107** of the hot water conduit **106** within the interior volume **114**.

Water heater appliance **100** extends between a top **108** and a bottom **109** along a vertical direction V. Thus, water heater appliance **100** is generally vertically oriented. Water heater appliance **100** can be leveled, e.g., such that casing **102** is plumb in the vertical direction V, in order to facilitate proper

operation of water heater appliance **100**. Water heater appliance **100** further includes an upper portion **160** and a lower portion **162** each defined along the vertical direction V. The upper portion **160** is thus generally above the lower portion **162** along the vertical direction V.

A drain pan **110** is positioned adjacent to the bottom **109** of water heater appliance **100** such that water heater appliance **100** sits on drain pan **110**. Drain pan **110** sits beneath water heater appliance **100** along the vertical direction V, e.g., to collect water that leaks from water heater appliance **100** or water that condenses on an evaporator **128** of water heater appliance **100**. It should be understood that water heater appliance **100** is provided by way of example only and that the present subject matter may be used with any suitable water heater appliance.

Turning now to FIG. **2**, as well as FIGS. **3** and **4**, water heater appliance **100** may include a sealed system **120** for heating water within interior volume **114** of tank **112**. The sealed system **120** generally operates in a heat pump cycle. Thus, water heater appliance **100** is commonly referred to as a "heat pump water heater appliance." Water heater appliance **100** may additionally include one or more auxiliary heating elements, such as an upper heating element **118** and/or a lower heating element **119**. Upper and lower heating elements **118** and **119** can be any suitable heating elements. For example, upper heating element **118** and/or lower heating element **119** may be an electric resistance element, a microwave element, an induction element, or any other suitable heating element or combination thereof. Lower heating element **119** may also be a gas burner.

Sealed system **120** may include a compressor **122**, a first condenser **124**, and a second condenser **126**. Each condenser **124**, **126** may be assembled in a heat exchange relationship with tank **112** in order to heat water within interior volume **114** of tank **112** during operation of sealed system **120**. Sealed system **120** may further include an evaporator **128**. Still further, sealed system **120** may include a first throttling device **130** between the first condenser **124** and second condenser **126**, and/or a second throttling device **132** between the second condenser **126** and the evaporator **128**. The evaporator **128** may be between and in fluid communication with the second condenser **126** and the compressor **122**. During operation of sealed system **120**, refrigerant may flow from the evaporator **128** through the compressor **122**. For example, refrigerant may exit evaporator **128** as a fluid in the form of a superheated vapor and/or high quality vapor mixture. Upon exiting the evaporator **128**, the refrigerant may enter compressor **122**. The compressor **122** may be operable to compress the refrigerant. Accordingly, the pressure and temperature of the refrigerant may be increased in the compressor **122** such that the refrigerant becomes a superheated vapor.

The first condenser **124** may be positioned downstream of and in fluid communication with the compressor **122**, and may be operable to heat the water within the interior volume **114** using energy from the refrigerant. For example, the superheated vapor from compressor **122** may enter condenser **124** wherein it transfers energy to the water within tank **112** and condenses into a saturated liquid and/or liquid vapor mixture. The second condenser **126** may be positioned downstream of and in fluid communication with the first condenser **124**, and may additionally be operable to heat the water within the interior volume **114** using energy from the refrigerant, such as by further condensing the refrigerant.

As discussed, in exemplary embodiments, a first throttling device **130** may be positioned between and in fluid communication with the first condenser **124** and the second condenser **126**. Refrigerant, which may be in the form saturated liquid vapor mixture, may for example exit the first condenser **124** and travel through the first throttling device **130** before flowing through the second condenser **126**. Throttling device **130** may generally expand the refrigerant, lowering the pressure and temperature thereof. The refrigerant may then be flowed through the second condenser **126**.

Additionally or alternatively, a second throttling device **132** may be positioned between and in fluid communication with the second condenser **126** and the evaporator **128**. Refrigerant, which may be in the form of high quality/saturated liquid vapor mixture, may for example exit the second condenser **126** and travel through the second throttling device **132** before flowing through the evaporator **128**. Throttling device **132** may generally expand the refrigerant, lowering the pressure and temperature thereof. The refrigerant may then be flowed through the evaporator **128**.

Throttling devices **130**, **132** may be any suitable components for generally expanding the refrigerant. For example, in some embodiments, as illustrated in FIG. **3**, a throttling device **130**, **132** may be a Joule-Thomson expansion valve **134**, also known as a "J-T valve" **134**. In other embodiments, as illustrated in FIG. **4**, a throttling device **130**, **132** may be an ejector **136**. In still other embodiments, a capillary tube, fixed orifice, or other suitable apparatus may be utilized as a throttling device **130**, **132**.

As is generally understood, various conduits may be utilized to flow the refrigerant between the various components of the sealed system **120**. For example, a conduit **140** may be utilized to flow refrigerant from the evaporator **128** to the compressor **122**. In some embodiments, a bypass conduit **142** may additionally be included in the sealed system **120**. The bypass conduit **142** may divert a portion of the refrigerant flowing from the evaporator **128** to the compressor **122**, and flow this portion of refrigerant to the throttling device **130**. Energy from the diverted refrigerant may be utilized to generate and transfer additional heat to the water in the interior volume **114**, thus increasing the efficiency of the system **120**. The bypass conduit **142** may, for example, include an inlet **144** in fluid communication with the conduit **140** and an outlet **146** in fluid communication with the throttling device **130**.

The use of two condensers **124**, **126** in the sealed system **120** advantageously increases the efficiency of the system **120** and the water heater appliance **100** in general. For example, the condensers **124**, **126** may take advantage of temperature gradients within the interior volume **114**. The condensers **124**, **126** may be designed and positioned such that the condensing temperatures thereof match the water temperatures generally proximate the condensers **124**, **126**. Accordingly, for each condenser **124**, **126**, a sufficient amount of heat is available in the refrigerant for a given amount of compressor **122** work.

In particular, the second compressor **126** may be positioned to take advantage of lower water temperatures which may exist in the water heater appliance **100**. In many cases, such as immediately after cold water is flowed into the tank **112**, a temperature gradient may exist, such as along the vertical direction V. Hotter water may be located towards the top **108**, such as in the upper portion **160**, above colder water which may be located towards the bottom **109**, such as in the lower portion **162**. The first condenser **124** may be positioned proximate an approximate location of the hotter water. The refrigerant may condense in the first condenser **124** at a temperature high enough to transfer heat to this hotter water. The second condenser **126** may be positioned proximate an approximate location of the colder water. The refrigerant may condense in the second condenser **126** at a temperature lower than that in the first condenser **124** but hot enough to warm the

colder water. Accordingly, the efficiency of the heat pump cycle, the sealed system **120**, and the appliance **100** in general may thus advantageously be improved, and associated energy costs may be decreased.

In exemplary embodiments, the first condenser **124** may thus for example be positioned above the second condenser **126** along the vertical direction V. Further, as illustrated, the first and second condensers **124**, **126** may each surround the tank **112**. For example, each condenser **124**, **126** may be wrapped around the tank **112**, such as in a generally helical manner as illustrated. Further, in exemplary embodiments, the first condenser **124** may surround the upper portion **160** of the tank **112** and the second condenser **126** may surround the lower portion **162** of the tank **112**. Such positioning of the condensers **124**, **126** may advantageously facilitate improved interaction with water in the interior volume **114**, such as water at varying temperatures, thus improving the efficiency and increasing the energy costs of the system **120** and appliance **100** in general.

Water heater appliance **100** may additionally include a temperature sensor **152**. Temperature sensor **152** may be configured for measuring a temperature of water within interior volume **114** of tank **112**. Temperature sensor **152** can be positioned at any suitable location within water heater appliance **100**. For example, temperature sensor **152** may be positioned within interior volume **114** of tank **112** or may be mounted to tank **112** outside of interior volume **114** of tank **112**. Temperature sensor **152** may further be positioned within upper portion **160** or lower portion **162**. When mounted to tank **112** outside of interior volume **114** of tank **112**, temperature sensor **152** can be configured for indirectly measuring the temperature of water within interior volume **114** of tank **112**. For example, temperature sensor **152** can measure the temperature of tank **112** and correlate the temperature of tank **112** to the temperature of water within interior volume **114** of tank **112**. Temperature sensor **152** can be any suitable temperature sensor. For example, temperature sensor **152** may be a thermocouple or a thermistor.

Water heater appliance **100** may further include a controller **150** that regulates operation of water heater appliance **100**. Controller **150** may be, for example, in operative communication with system **120** (such as the compressor **122** and/or other components thereof), auxiliary heating elements, and/or temperature sensor **152**. Thus, controller **150** can selectively activate system **120** and/or auxiliary heating elements in order to heat water within interior volume **114** of tank **112**.

Controller **150** includes memory and one or more processing devices such as microprocessors, CPUs or the like, such as general or special purpose microprocessors operable to execute programming instructions or micro-control code associated with operation of water heater appliance **100**. The memory can represent random access memory such as DRAM, or read only memory such as ROM or FLASH. The processor executes programming instructions stored in the memory. The memory can be a separate component from the processor or can be included onboard within the processor. Alternatively, controller **150** may be constructed without using a microprocessor, e.g., using a combination of discrete analog and/or digital logic circuitry (such as switches, amplifiers, integrators, comparators, flip-flops, AND gates, and the like) to perform control functionality instead of relying upon software.

The present disclosure is further directed to methods for operating water heater appliances. A method may include, for example, the step of flowing a refrigerant through a compressor **122**, as discussed above. A method may further include, for example, the step of flowing the refrigerant from the compressor **122** through a first condenser **124** surrounding a tank **112** of the water heater appliance **100**, as discussed above. A method may further include, for example, the step of flowing the refrigerant from the first condenser **124** through a second condenser **126** surrounding the tank **112** of the water heater appliance **100**, as discussed above.

In some embodiments, a method according to the present disclosure may further include the step of flowing the refrigerant from the second condenser **126** through an evaporator **128**, as discussed above. Additionally, in some embodiments, a method according to the present disclosure may include flowing the refrigerant from the second condenser **126** through a throttling device **132** before flowing the refrigerant through the evaporator **128**, as discussed above.

Further, in some embodiments, a method according to the present disclosure may include flowing the refrigerant from the first condenser **124** through a throttling device **130** before flowing the refrigerant through the second condenser **126**, as discussed above. Still further, a method according to the present disclosure may include diverting a portion of the refrigerant from the evaporator **128** to the throttling device **130**, as discussed above.

This written description uses examples to disclose the invention, including the best mode, and also to enable any person skilled in the art to practice the invention, including making and using any devices or systems and performing any incorporated methods. The patentable scope of the invention is defined by the claims, and may include other examples that occur to those skilled in the art. Such other examples are intended to be within the scope of the claims if they include structural elements that do not differ from the literal language of the claims, or if they include equivalent structural elements with insubstantial differences from the literal languages of the claims.

What is claimed is:

1. A water heater appliance, comprising:

a tank defining an interior volume; and

a sealed system for heating water within the interior volume, the sealed system comprising:

a compressor operable to compress refrigerant;

a first condenser downstream of and in fluid communication with the compressor, the first condenser operable to heat water within the interior volume using energy from the refrigerant;

a second condenser downstream of and in fluid communication with the first condenser, the second condenser operable to heat water within the interior volume using energy from the refrigerant;

a throttling device between and in fluid communication with the first condenser and the second condenser;

an evaporator between and in fluid communication with the second condenser and the compressor; and

a bypass conduit, the bypass conduit comprising an inlet in fluid communication with a conduit flowing refrigerant from the evaporator to the compressor and an outlet in fluid communication with the throttling device.

2. The water heater appliance of claim **1**, wherein the first condenser is positioned above the second condenser along a vertical direction.

3. The water heater appliance of claim **1**, wherein the first condenser and the second condenser each surround the tank.

4. The water heater appliance of claim **1**, wherein the tank comprises an upper portion and a lower portion each defined along a vertical direction, and wherein the first condenser surrounds the upper portion and the second condenser surrounds the lower portion.

5. The water heater appliance of claim 1, wherein the throttling device is a J-T valve.

6. The water heater appliance of claim 1, wherein the throttling device is an ejector.

7. The water heater appliance of claim 1, wherein the sealed system further comprises a second throttling device between and in fluid communication with the second condenser and the evaporator.

8. The water heater appliance of claim 1, further comprising an auxiliary heating element.

9. The water heater appliance of claim 1, further comprising a hot water conduit and a cold water conduit each extending into the interior volume, the cold water conduit having a length within the interior volume greater than a length of the hot water conduit within the interior volume.

10. A method for operating a water heater appliance, the method comprising:

flowing a refrigerant through a compressor;

flowing the refrigerant from the compressor through a first condenser surrounding a tank of the water heater appliance;

flowing the refrigerant from the first condenser through a second condenser surrounding the tank of the water heater appliance;

flowing the refrigerant from the first condenser through a throttling device before flowing the refrigerant through the second condenser;

flowing the refrigerant from the second condenser through an evaporator; and

diverting a portion of the refrigerant from the evaporator to the throttling device.

11. The method of claim 10, further comprising flowing the refrigerant from the second condenser through a throttling device before flowing the refrigerant through the evaporator.

12. The method of claim 10, wherein the throttling device is a J-T valve.

13. The method of claim 10, wherein the throttling device is an ejector.

14. The method of claim 10, wherein the tank comprises an upper portion and a lower portion each defined along a vertical direction, and wherein the first condenser surrounds the upper portion and the second condenser surrounds the lower portion.

* * * * *